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Operation Manual for the Six-foot Integrating Sphere, Hardy

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This document describes the state of the six-foot integrating sphere source, known as Hardy, located at the NASA GSFC Code 920.1 Calibration Facility. Additionally, this document outlines the operation procedures for this source.

Keywords: Hardy, Six-foot Integrating Sphere, Integrating Sphere, Power Supply

1.0 Introduction and General Description

1.1 General Description

The integrating sphere source consists of two parts: a 72” diameter sphere source and a source system power supply (Figure 1).

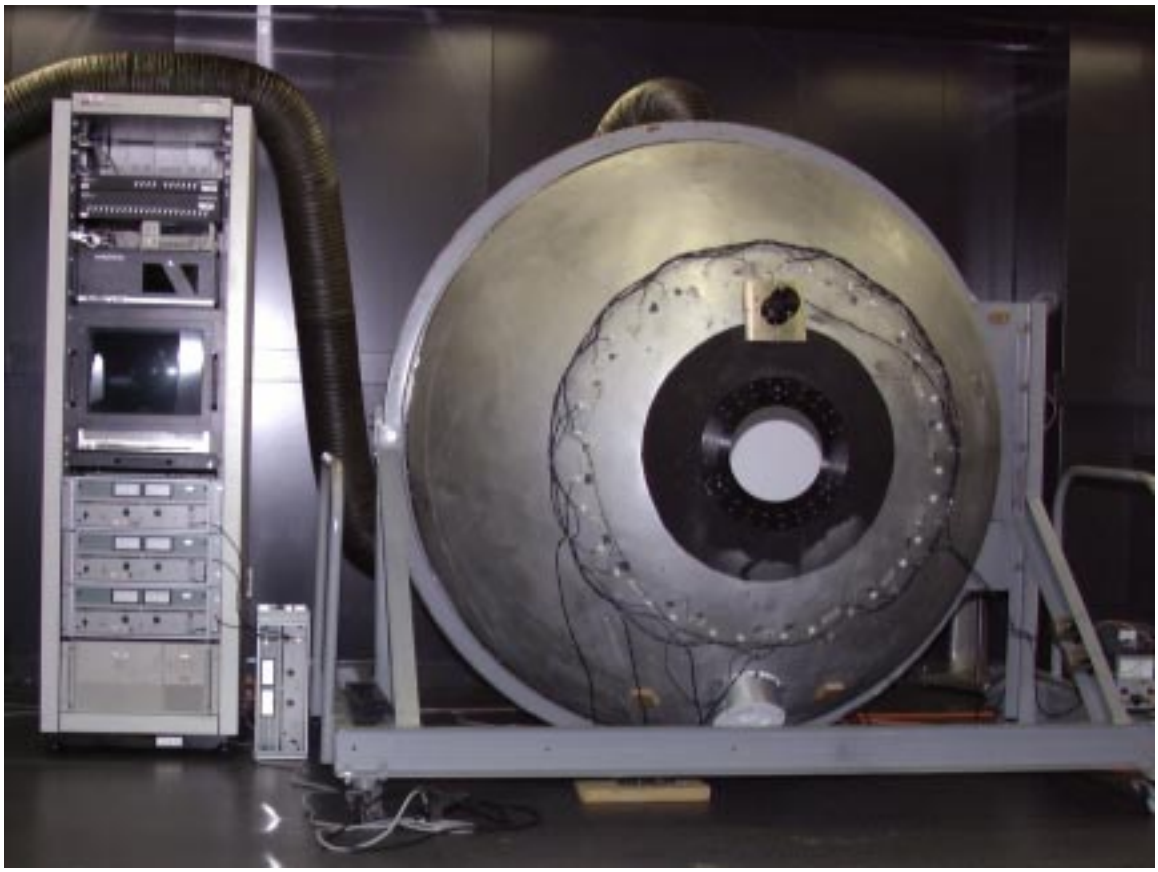

Figure 1 - The Hardy Source System.

The sphere consists of two (2) hollow laminated fibreglas hemispheres. The rear hemisphere is mounted to the front hemisphere by hinges on one side and secured on the other by a latch. The front hemisphere is mounted to a support frame. The front hemisphere also has a 10” diameter exit aperture mounted at the midpoint of the

hemisphere (represented by the black circle in Figure 2). Inside the sphere, sixteen (16) 200-watt quartz tungsten halogen lamps, GE type Q6.6A/T4/5CL, are mounted symmetrically around the exit port (represented by the dashed circle in Figure 2). A single conical section aluminum baffle is mounted so that light from the lamps does not directly exit the sphere. Several coats of $BaSO_4$ cover the sphere interior and the conical baffle, providing a higlhy diffuse and reflective surface.

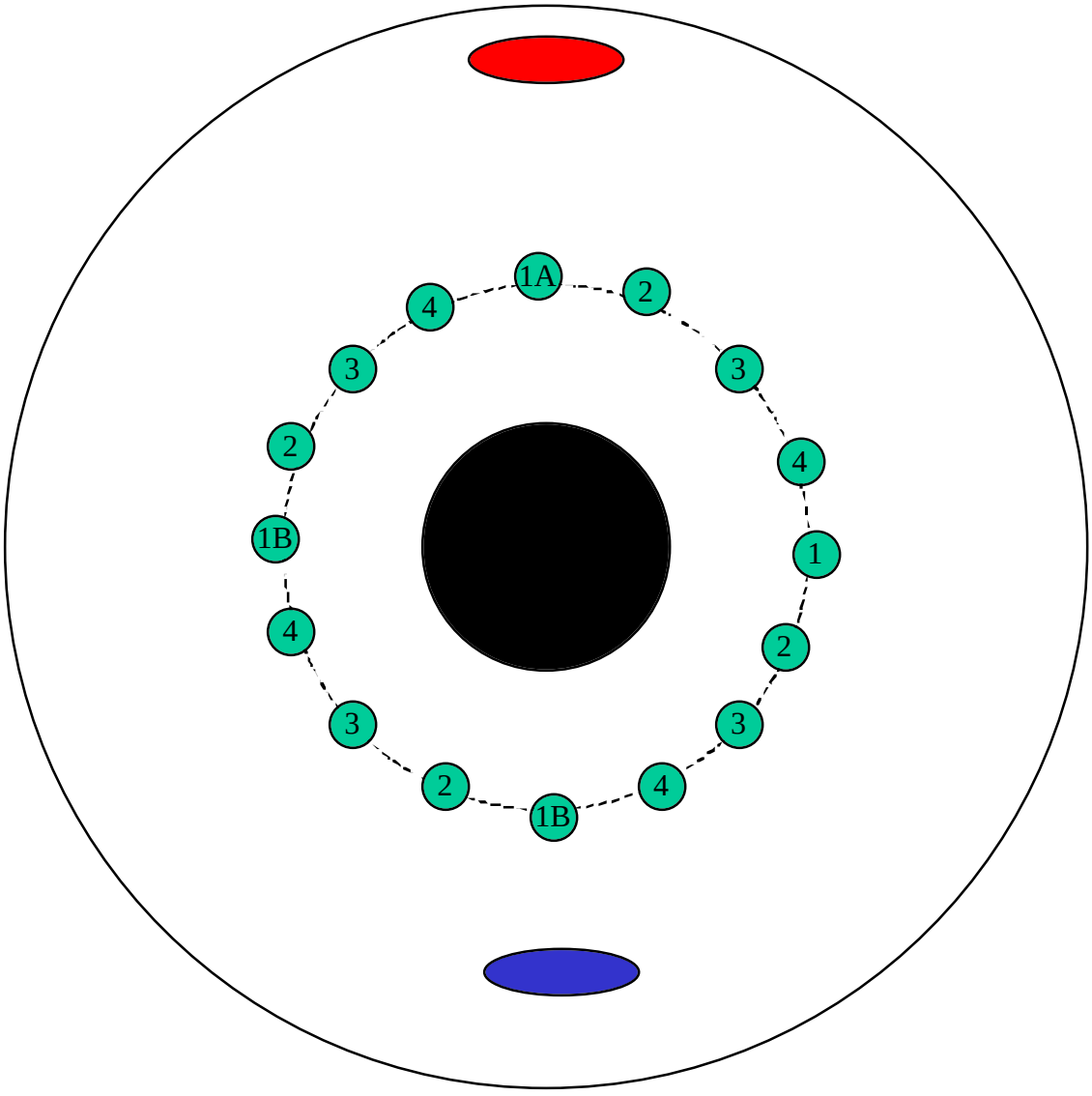

Figure 2 - Hardy Arrangement

Sixteen 200-watt lamps (represented by the green circles in Figure 2) produce a great quantity of heat. To remove most of the heat, and to reduce temperature variations which may affect the calibration, a baffled exhaust vent is located at the top of the rear hemisphere (represented by the top red oval in Figure 2). This exhaust vent is connected to the building exhaust ventilation system. Additionally, a baffled inlet vent is located below the exit aperture on the front hemisphere (represented by the bottom blue oval in

Figure 2), providing a future connection for cooled, dehumidified air to be introduced into the sphere.

The lamp within a bank are arranged so that when the bank is ON, illumination within the sphere is as symmetrical as possible. In Figure 2, the green circles represent one lamp each. The number within the circle corresponds to the bank to which the lamp is connected. Three lamps also have a letter. These are the lamps which are bypassed when the shunt relays are enabled.

The inlet and exhaust baffles (Figure 3) are identical. They consist of an 8" diameter tube, in which are mounted three disks. The two outer disks have a cutout which provides ventilation. The disks are secured and separated by 1/2" standoffs. To minimize absortive areas within the sphere, the disks and tube interior are coated with the same $BaSO_4$ coating as the sphere interior.

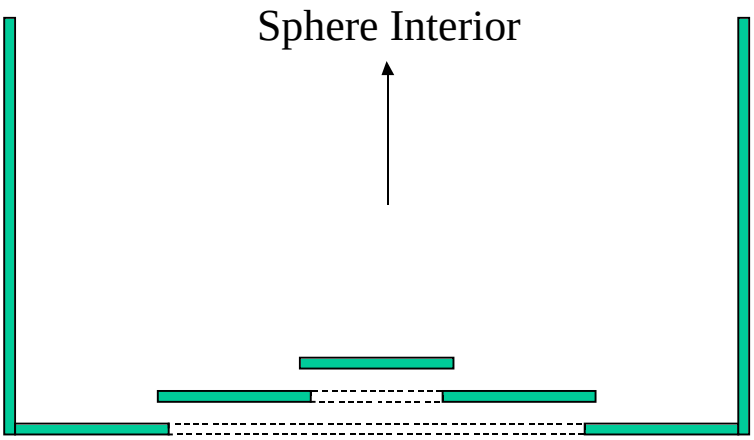

Figure 3 - Inlet & Exhaust Baffle Arrangement

The source system power supply includes a four-channel 16-bit DAC, a multimeter, a multiplexer switch, four power supplies, shunt resistors, an UPS, and a control computer. A software tool sets the DAC output level for each channel.

1.2 Electonic Components

The primary components of the source system power supply are:

- Four DC lamp power supply units, Kikusui PAD160-7L.
- One four-channel 16-bit DAC, IOTech DAC488/16HR.
- Four shunt resistors.
- One rotary multiplexer switch.
- One digital multimeter, Keithley 8842.
- One control computer, Marathon RackMac Macintosh clone.

There are two secondary components of the source system power supply. They are:

- Two bypass relays, which are wired to shunt one and two lamps, respectively, on lamp bank 1.

- Two 24V DC power supplies which provide power for the two bypass relays.

1.3 Circuit Theory

The DC lamp power supplies are operated in the constant current mode, sourcing current through four lamps each. Additionally, a standard 0.01Ω ammeter shunt is in series with the lamps. The combination of power supply, lamps, and shunt is referred to as a lamp bank. This is represented in Figure 4 by the contents of the dashed line. The power supply output current is set by an external control voltage signal.

Four control voltage signals are generated by the 16-bit DAC, one for each lamp power supply. Communication between the DAC and control computer occurs over a GPIB interface.

The control computer runs the “PS Control.vi” program, which allows the operator to adjust DAC output.

The shunt outputs are connected to the DMM through the rotary multiplexer switch. The switch is used to select the shunt output to be measured and displayed by the DMM. The DMM measures a voltage proportional to the current through the shunt.

The DMM measurement is used by the operator to adjust the current for the bank. The operator performs this adjustment by changing the DAC output via the “PS Control.vi” program.

The two bypass relays, when de-energized, insert a short across a lamp or lamps. This permits current to flow through the short, rather than the lamp, effectively disabling the lamp. One bypass relay bypasses one lamp, the other bypasses two. Energizing the relays opens the short, enabling current to flow through the lamp. Control of the relay state is accomplished by turning the 24V DC power supplies on to energize, off to de-energize.

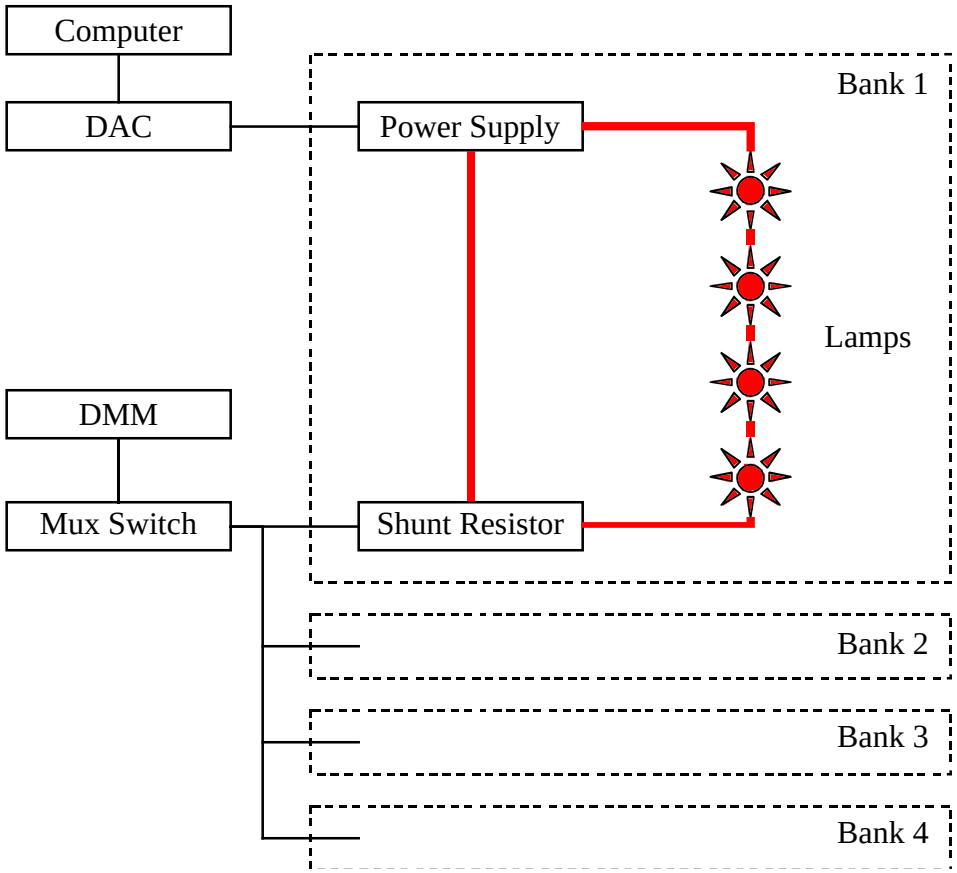

Figure 4 - Electrical Block Diagram

2.0 System Installation and Operation
2.1 Installation requirements
2.1.1 Power
Five standard 120V, 20A, 60Hz circuits are required. Each lamp power supply is connected to a separate power circuit, the UPS is connected to the fifth power circuit.

The computer obtains its power directly from the UPS. The computer monitor and all other instruments in the rack obtain power from the rack power distribution unit (PDU). The bypass relay power supplies are powered from the PDU through an extension cord.

2.1.2 Interconnection
Four cables connect the lamp power supplies to the lamp banks through a Jones strip located under the front hemisphere of the source. Each cable is labeled with a bank

number and + or -, denoting positive and negative circuit sides. Please note that this interconnection is hardwired.

2.2 Initial Control Settings

2.2.1 Lamp Power Supplies
Power Breaker – OFF
Voltage knob – Fully clockwise
Current knob – Arbitrary

2.2.2 UPS
UPS – ON

2.2.3 Instruments
DMM – ON
DAC – ON
Computer monitor – ON

2.2.4 Multiplexer switch
Position is arbitrary.

2.2.5 Rack PDU
Master power switch – OFF

2.2.6 Control Computer
Computer – OFF

2.2.7 Lamp Shunt Relay Power Supplies
Upper supply power – OFF
Upper supply meter select switch – Volts

Lower supply power – OFF
Lower supply meter switch – Volts

2.3 System Operation

2.3.1 Preparation
Verify that all four lamp power supplies are OFF by checking the power breaker on the power supply front panel is in the OFF (down) position (Figure 5)

Figure 5 - Lamp Power Supplies #2 & 3 in OFF state.

Verify that UPS power is ON by checking the front panel (Figure 6). If one or more LEDs are lit, the UPS is ON. If OFF, turn it ON by pressing the circular I switch on the UPS front panel. The unit will run a self test during which the unit will beep and a fan in the UPS will start.

Figure 6 - Lamp Power Supplies & UPS

Turn the rack PDU ON by flipping the master power switch to the ON position (Figure 7). When ON, an indicator built into the switch will be lit. The PDU master power switch is located on the front top right corner of the rack and is covered by a clear protective shield.

Verify that the instruments and monitor are on (Figure 7). When power is applied, the DMM display will light up, the DAC power indicator will light, and the monitor will display a “Check Signal Cable” message.

Figure 7 - System Instruments in the ON state.

Turn ON the lamp shunt relay power supplies (Figure 8). These supplies are located on the right leg of the sphere support frame. When on, the relays will click, and the power indicator light will glow. Verify the meters read approximately 20 volts; the exact setting is not critical, as long as it is between 18 and 24 volts.

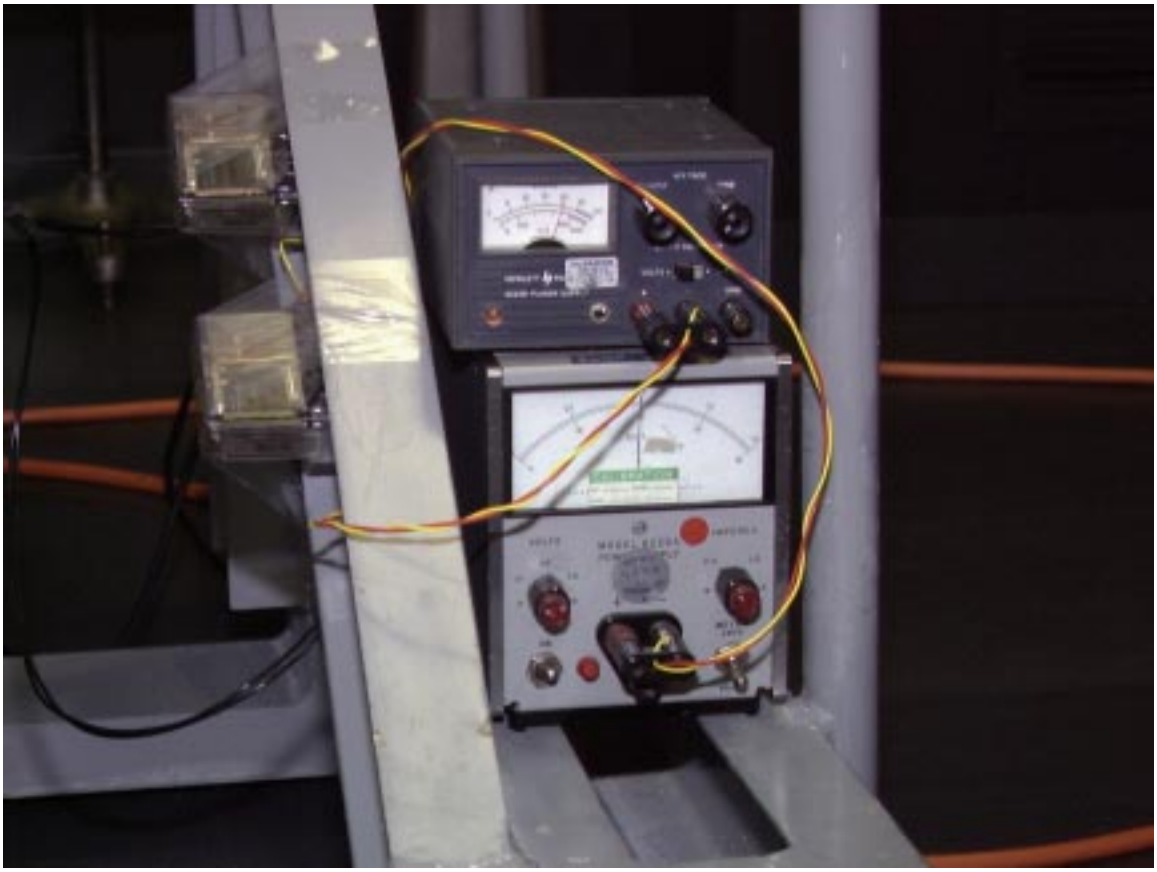

Figure 8 - Lamp Shunt Relay Power Supplies in the ON state.

Turn ON the computer by pressing the power key on the keyboard (the key with the left pointing hollow arrowhead). The computer will start up, and the monitor will display the Macintosh startup screen. After the computer boots, it will automatically start the “PS Control.vi” tool.

Turn the multiplexer control switch to the fully counterclockwise position (Figure 9).

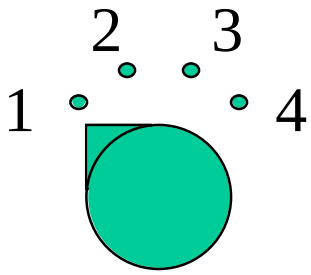

Figure 9 - Multiplexer Switch Positions

The system is now ready for operation.

2.3.2 Startup

Once the computer has completed its boot process, it will automatically start the “PS Control.vi” tool, shown in the following figures.

To initialize the system and start lamp operation, ensure the “Initialize” button is pressed on the “PS Control.vi” window (Figure 11). If the button is not pressed (Figure 10), move the pointer over the button and click.

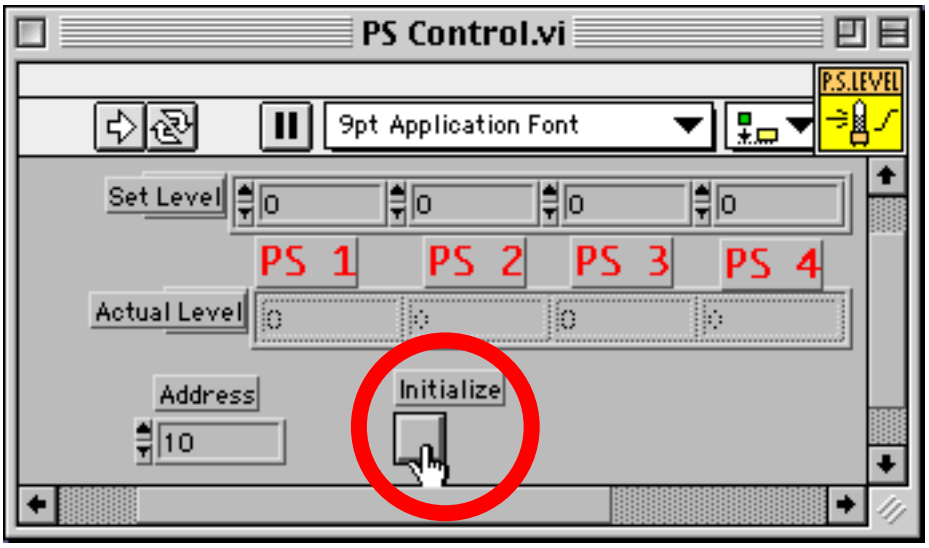

Figure 10 - Initialize button not pressed.

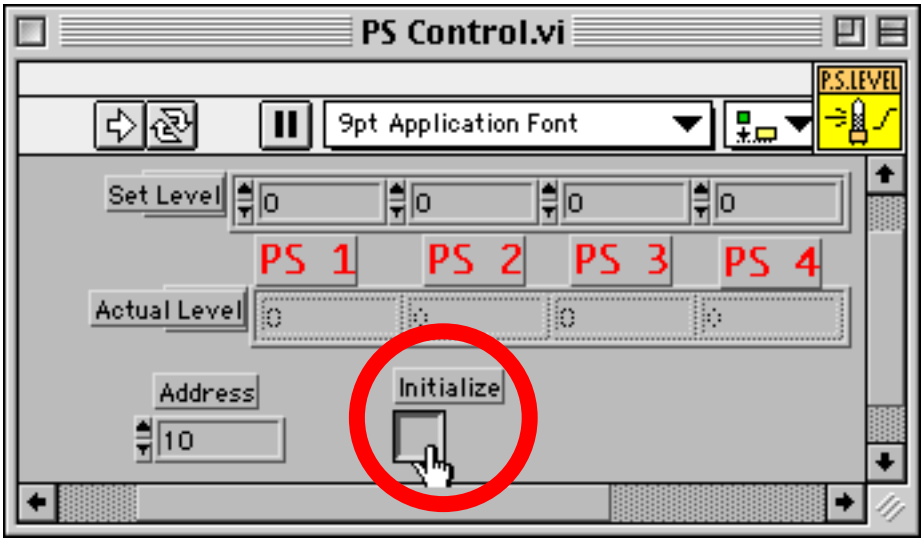

Figure 11 - Initialize button pressed.

To start the program and run the initialization sequence, move the pointer to the Run button and click on it, as shown in the next two figures.

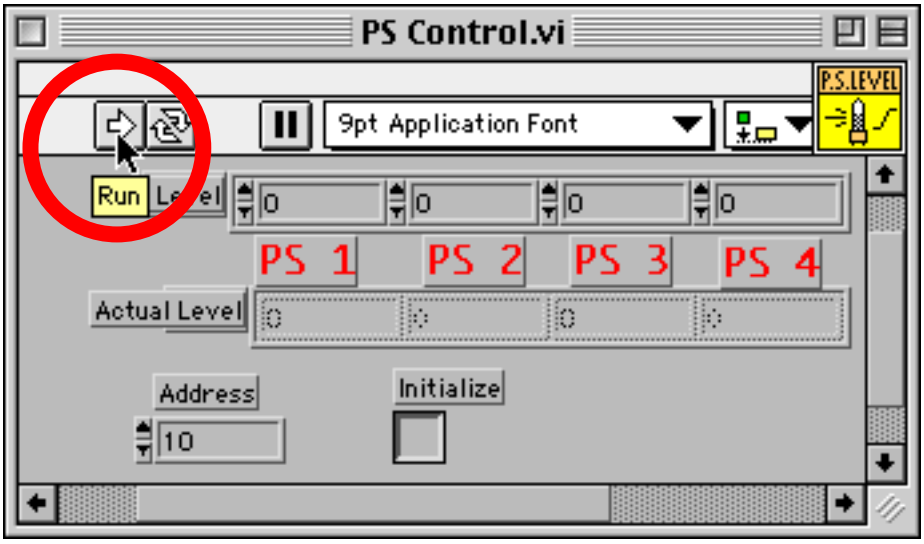

Figure 12 - The Run button

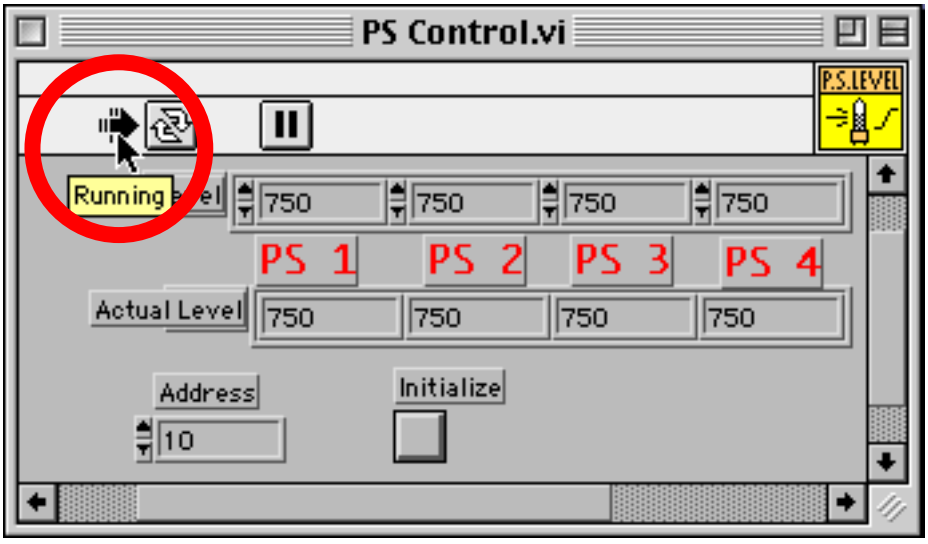

Figure 13 - The control program is running.

At this point, the DACs are starting to ramp up. Quickly turn all of the lamp power supplies ON.

The “PS Control.vi” tool will take just over one minute to ramp up the lamp power supply current to a point near the nominal lamp operating current. The sphere should now be left alone for one half to one hour to warm up.

2.3.4 Operation

2.3.4.1 Introduction

The lamp banks are numbered 1 through 4. On the lamp power supplies, the bank number is located on a red spot on the power supply front panel (Figure 5). On the “PS Control.vi” front panel, the banks are labeled PS 1 through PS 4 (Figure 14).

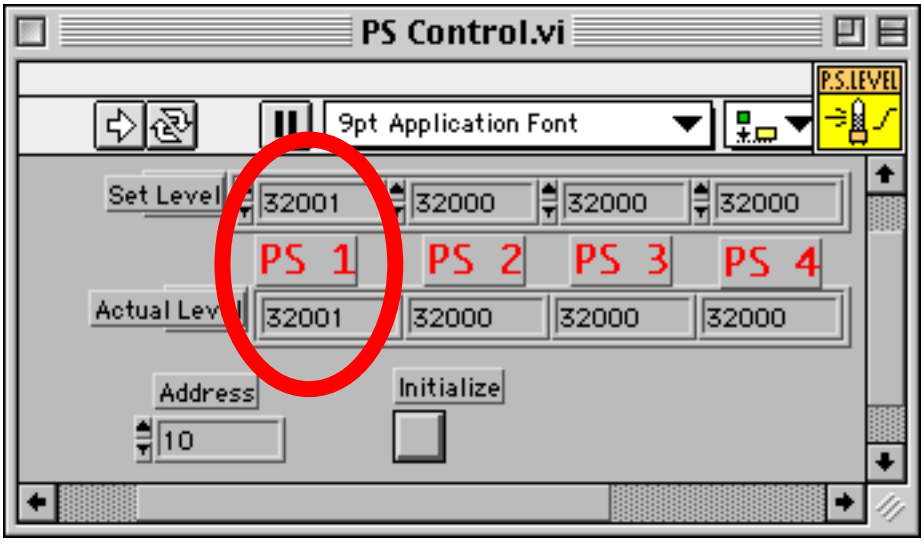

Figure 14 - Lamp bank labeling

Each lamp bank has an ammeter shunt (rated 10A, 100mv) in series with the lamps. The current in a particular bank is derived by measuring the potential drop across the shunt, then dividing this measurement by 10mv/A. The shunt potential drop is displayed on the DMM. Thus, a DMM reading of 30mv corresponds to a current of 3.0 A. The desired lamp current for all lamp banks is 6.51 A.

On the “PS Control.vi”, the “Set Level” display, located above the red bank identifier is the “Set Level” display, below is the “Actual Level”. These level displays indicate the desired and actual DAC output step count.

2.3.4.2 Increasing the Current
To increase the current in a lamp bank, the following five steps must be performed.

Move the multiplexer control switch to the appropriate postion for the bank to be adjusted. There are four positions corresponding to lamp banks 1 through 4 (Figure 9).

Start the “PS Control.vi” program in run continuously mode. To do this, move the pointer to the Run Continuously button and click on it, as shown in the next two figures.

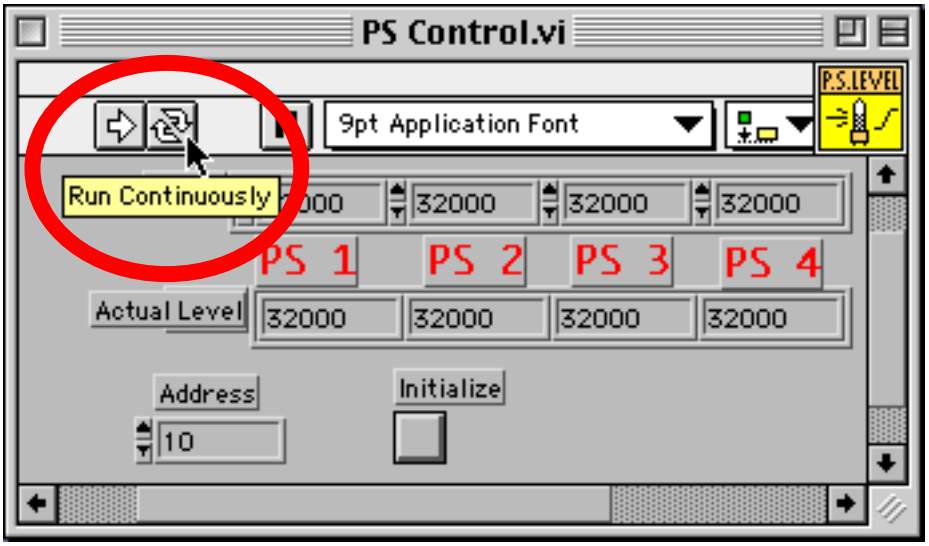

Figure 15 - The Run Continuously Button

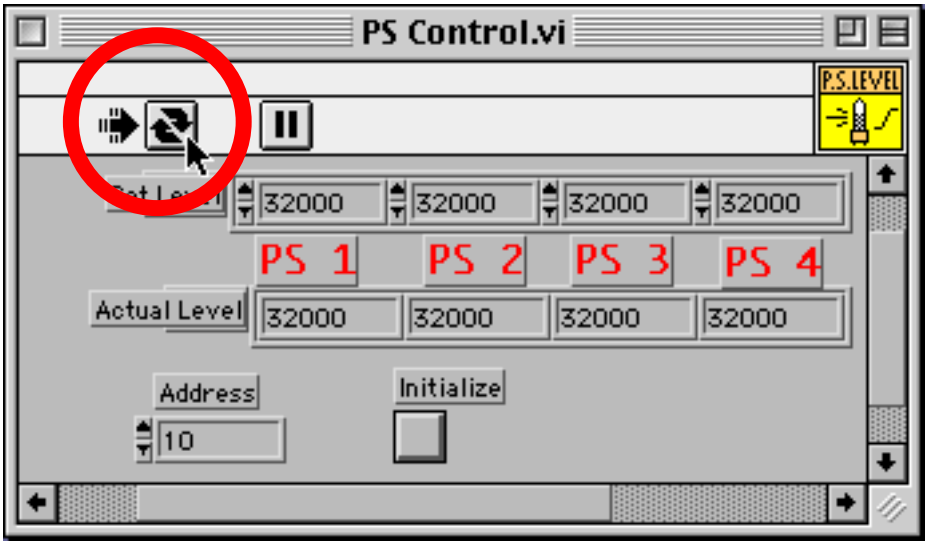

Figure 16 - The control program is running continuously.

To increase the current in the bank, click on the up arrow just to the left of the “Set Level” display for the bank. (Figure 17 shows bank PS 1 being increased).

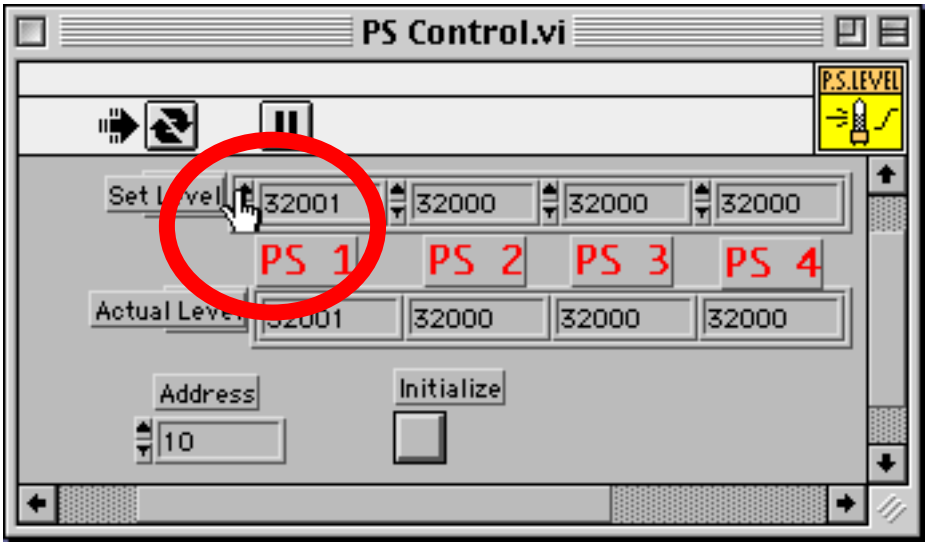

Figure 17 - Bank 1 current being increased.

Monitor the DMM display as the current is increased. When the DMM display reads the correct voltage drop across the ammeter shunt, the current is set to the proper level.

Take the program out of run continuously mode. To do this, click on the run continuously button. When the "PS Control.vi" program completes the present iteration, it will completely stop.

2.3.4.3 Reducing the current

The steps for reducing the current are the same as those for increasing the current. The only difference is that the down arrow just to the left of the "Set Level" display must be pressed to reduce the current. (Figure 18 shows bank PS 1 being reduced).

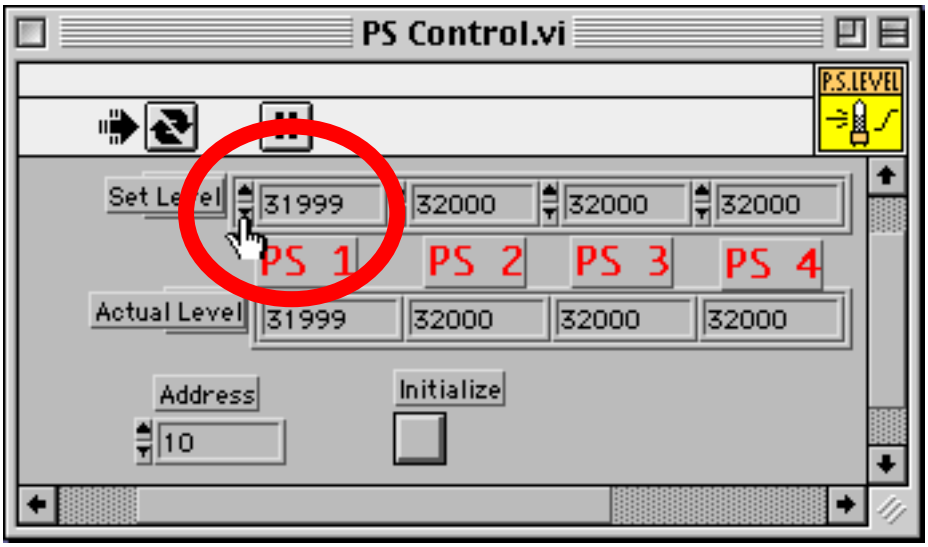

Figure 18 - Bank 1 current being decreased.

2.3.4.4 Turning Lamps Off
There are five authorized illumination levels for Hardy: 16, 12, 6, 2, and 1 lamps. These illumination levels are achieved by a combination of turning various banks off and enabling lamp shunt relays.

To turn a bank of lamps off, switch the bank power supply off.

To enable a lamp shunt, turn the lamp shunt relay power supply off. The shunt relay power supplies are located on the right side of the sphere support frame. When the upper power supply is off, one lamp is shunted. When the lower power supply is off, two lamps are shunted.

The following table outlines the bank power supply and shunt power supply states (on or off) to achieve the authorized illumination levels.

Number of Lamps ON	Power Supply #1	Power Supply #2	Power Supply #3	Power Supply #4	Upper Shunt PS	Lower Shunt PS
16	ON	ON	ON	ON	ON	ON
12	ON	OFF	ON	ON	ON	ON
6	ON	OFF	OFF	ON	ON	OFF
2	ON	OFF	OFF	OFF	ON	OFF
1	ON	OFF	OFF	OFF	OFF	OFF

CAUTION: ALWAYS START AT THE 16 LAMP ILLUMINATION LEVEL, THEN GO TO 12, THEN 6, THEN 2, AND FINALLY 1. DO NOT INCREASE THE ILLUMINATION LEVEL WITHOUT RE-INITIALIZING THE SYSTEM. DOING SO WILL SHOCK THE LAMPS AND SIGNIFICANTLY SHORTEN LAMP LIFE.

2.3.4.5 Turning Lamps On
To turn lamps back on, the system must be re-initialized. To re-initialize the system, first turn the bank power supplies off, then turn the lamp shunt relay power supplies on. Next go to section 2.3.2, and follow the instructions for initializing the system.

2.3.4.6 Shutting Down
To shut down the system:

Ensure the bank power supplies are OFF.

Ensure the lamp shunt relay power supplies are ON.

To shut down the control computer, press the power key on the keyboard (the key with the left pointing hollow arrowhead). When the Restart/Sleep/Cancel/ShutDown dialog box appears, hit return or click on the ShutDown button. The computer will go through its shutdown process.

Turn the rack PDU master power switch OFF.